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GEORGIA INSTITUTE OF TECHNOLOGY

Engineering Experiment Station

PROJECT INITIATION

Date: 3/23/71

Project Title: Low Frequency Oscillator for Wood Preservative Process

Project No.: A-1320

Project Director: Mr. J. F. Kinney

Sponsor: Osmose Wood Preserving Company

Effective . . . . . March 23, 1971. . . . . Estimated to run until: . . . September 22, 1971. . . .

Type Agreement: . . Standard Industrial Research Agreement . . . Amount: $ 3,400* . . . .

Reports: Monthly Progress Reports

Contact Person: Mr. W. C. Bartholomew
Osmose Wood Preserving Company
P. O. Box 168
Griffin, Georgia 30223

*Funding for Phase I only.

Assigned to . . . . Chemical Sciences & Materials . . . . Division

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GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

June 4, 1971

Osmose Wood Preserving Company
P. O. Box 168
Griffin, Georgia 30223

Attention: Mr. W. C. Bartholomew

Subject: Progress Report covering period March 23 to May 23, 1971
Project A-1320
"Low Frequency Oscillator for Wood Preservative Process"

Dear Sir:

The equipment listed in the proposal has arrived and has been assembled into an exploratory test unit. Pressure cells will be fitted to the system within the next few days.

A recorder originally planned for use on this project will not be available. Consequently, the hardware will be moved to Research Area 2, where both chart recorder and oscillograph recorder are available for use. This move is anticipated during the first week of June.

Yours very truly,

J. F. Kinney
Project Director

JFK/cdg

GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

July 16, 1971

Osmose Wood Preserving Company
Post Office Box 168
Griffin, Georgia 30223

Attention: Mr. W. C. Bartholomew

Subject: Progress Report Covering the Period May 24, 1971 to July 9, 1971
Project A-1320
"Low Frequency Oscillator for Wood Preserving Process"

Dear Sir:

The exploratory test unit has been set up in the Research Area 2, with the pressure cells monitored by a Dynagraph recorder and a dual-beam oscilloscope.

Two techniques of achieving the pressure pulsing are to be tried. The first is a water-hammer type, shown in Figure 1. Periodic closing of the ball-valve should create a pressure pulse in the line. Preliminary tests have indicated that the water flow in the 1/2" pipe is insufficient to introduce a significant water hammer effect. Reduction of the pipe area should increase the velocity of flow and hence p d v; this should increase the pressure pulse available.

The second technique to be tried will be that illustrated in Figure 2. Periodic opening of the ball valve should permit pulses of pressure to be transmitted to the water tank.

Tests of both systems should be accomplished early in August.

Respectfully submitted,

John F. Kinney
Project Director

JFK:mhf

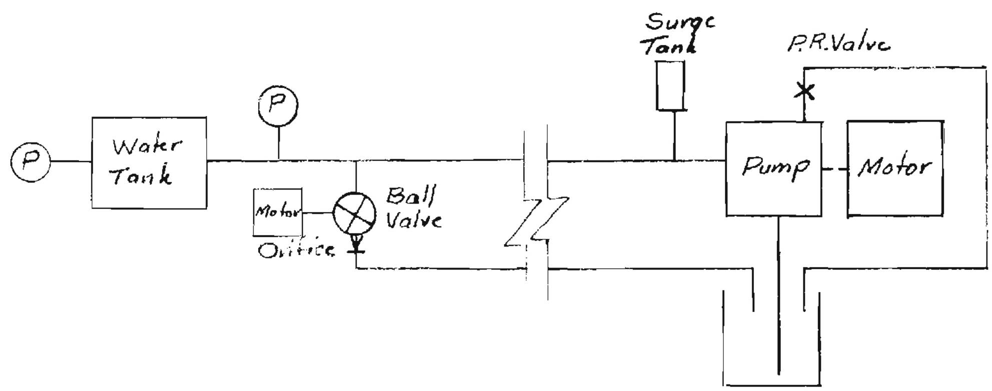

Figure 1. Water-Hammer Technique

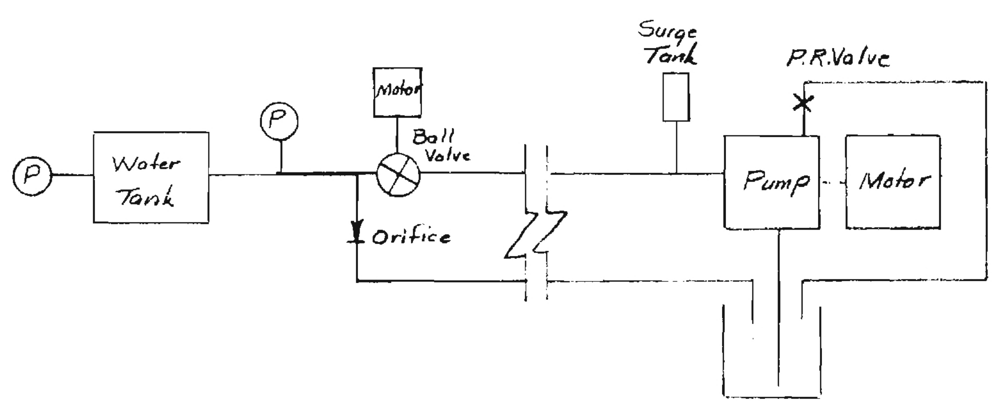

Figure 2. Valve-Pulsing Technique

GEORGIA INSTITUTE OF TECHNOLOGY
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September 8, 1971

Osmose Wood Preserving Company
Post Office Box 168
Griffin, Georgia 30223

Attention: Mr. W. C. Bartholomew

Subject: Progress Report Covering the Period July 10, 1971 to August 31, 1971
Project A-1320
"Low Frequency Oscillator for Wood Preserving Process"

Dear Sir:

The tests on the experimental equipment at Georgia Tech are essentially complete. The arrangement No. 2 in the previous Progress Report, with the ball valve in the pump return line, appears to be most promising, particularly with a small pump.

The instrumentation arrangement will have to be modified and then recalibrated to facilitate carrying the instrumentation to Griffin to install it on the equipment there. The modification as well as sketches for instrumenting the Griffin equipment should be completed during the coming month.

Respectfully submitted,

John F. Kinney
Project Director

JFK/sc

GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

November 11, 1971

Osmose Wood Preserving Company
Post Office Box 168
Griffin, Georgia 30223

Attention: Mr. W. C. Bartholomew

Subject: Progress Report Covering the Period September 1, 1971 to November 8, 1971
Project A-1320
"Low Frequency Oscillator for Wood Preserving Process"

Dear Sir:

The rotating valve seal as originally incorporated in the valve, leaked seriously after only a few hundred rotations at 5 RPS. This valve seal was modified to provide alignment of the stem as well as a seal. However, operation at pressures up to 300 psi at approximately 20 RPS again introduced leakage after several thousand revolutions.

The valve seal is being modified to provide sealing at the necessary pressures and cyclic rates. Following modification, the valve will be tested to evaluate the seal.

Sketches of the modification of the retort system will be forwarded to the sponsor in the next week or two. However, the valve design must be stabilized first.

Respectfully submitted,

John F. Kinney
Project Director

JFK/sc

FINAL REPORT

LOW–FREQUENCY OSCILLATOR FOR WOOD PRESERVATION PROCESS

By

J. F. Kinney and J. B. Langley

Prepared for

OSMOSE WOOD PRESERVING CO.
Griffin, Georgia

Under

Standard Industrial Agreement
dated 9 March 1971

March 1975

1975

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
Atlanta, Georgia 30332

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
Atlanta, Georgia 30332

FINAL REPORT

Low-Frequency Oscillator for Wood Preservative Process

EES/GIT Project A-1320

(Phases I and IA)

By

J. F. Kinney and J. B. Langley

Prepared for

OSMOSE WOOD PRESERVING CO.
Griffin, Georgia

March 1975

TABLE OF CONTENTS

LIST OF FIGURES

I. SUMMARY

The objective of the program reported here was to determine the necessary parameters to permit designing a low-frequency sonic oscillator capable of reducing the time required to treat lumber with liquid preservative. A technique for utilizing resonant oscillatory pressures in the pressure treatment of wood with preservative was shown to increase the penetration of the preservative, at a modest cost of additional equipment. The work was prinicpally done in an experimental retort at Griffin, Georgia.

Two factors produce unpredictable changes in apparent system compressibility during the treatment cycle from one load to another; these are the variability of the wood in each charge of the retort and the release of air when preservative displaces air within the wood structure. The work reported herein gives some insight as to the extent and direction of this apparent change.

An electronic control circuit was designed, fabricated, and tested at the experimental retort in Griffin. This device holds the oscillatory fluctuations near resonance during the treatment cycle. The control unit requires only an initial adjustment of the valve timing for each retort change; thereafter, the control unit adjusts valve timing to maintain near-resonant conditions throughout the treatment of the charge.

II. INTRODUCTION

Sonic pile-driving equipment is operated by attaching an electrical transducer to the top of the pile and then tuning the transducer/pile system to resonance, which produces forces driving the pile into the ground. It has been noted that a "shower" of creosote oil emerges from all surfaces of the pile as it is being driven down. R. Z. Page and B. E. Reed [1] reasoning that the "shower" of creosote indicated an opening and closing of the pores in the wood under the sonic influence, attempted to adapt this concept to the absorption of wood preservative in a pressurized vessel. J. H. Barnett, Jr., in 1968 presented data [2] on the use of a jack-hammer to excite a preservative treatment tank filled with wood and preservative, and was able to reduce treatment time to 5% to 16% of the normal treatment time.*

Barnett believed that the steep front of the shock wave produced by the Sontek equipment (the jack-hammer driven excitation system) was responsible for the reduction in treatment time. However, others have recorded the Sontek pressure pulses in a large treatment tank and observed only low-level, rounded pressure pulses, rather than steep-fronted shock-waves. No treatment plants are known to be using this process currently, primarily because of the maintenance problems associated with the striker rod, which apparently had a very short life.

Current processes generally utilize one of several treatment cycles which typically involve filling the tank (retort) with wood, reducing the pressure in the retort to 25 inches of mercury vacuum or below, filling the tank with preservative, pressurizing the retort using a centrifugal pump and pressure relief valve, holding the pressure for a time dependent on the characteristics required of the treated wood, relieving the pressure on the retort, draining the retort of preservative, and allowing a drip period before removing the treated wood from the retort. Southern yellow pine requires approximately one hour at 125 psig to treat to "refusal"** with the process outlined above; Douglas fir required approximately four hours at 125 psig.

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*The jack-hammer unit apparently operated in the range of 300-600 cycles per minute (5-10 hertz).

** "Refusal" is defined as the point where the wood apparently refuses to take up more preservative.

The wood treatment retorts are steel tanks 40 to 120 feet long with diameters up to about 60 inches. The natural (volume) resonance of these tanks is on the order of one Hertz or lower.* The Sontek equipment pulsed the retort in a manner that might have excited the longitudinal resonant frequency of the loaded retort, which for one 60 feet long could have been in the vicinity of 5 Hertz. However, in this case, some of the hammer blow on the diaphram would be expected to be observed in the internal pressure waveform. This apparently was not observed in the pressure measurements.

In the work presented herein, a somewhat different approach was taken to achieve a pressure variation in the retort, while using only moderate additional equipment. This approach involves using a rotary valve to generate variations of flow out of the retort, producing variations of pressure about some mean pressure level. The intensity level of the pressure variations produced is dependent on the valve size and rotation rate, retort volume, retort pump and relief-valve sizes, and the pressure setting of the relief valve.

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*The experimental retort at Griffin (18-inch diameter by 20 feet long) resonated in the vicinity of 3 Hertz. A larger retort would have a lower resonant frequency.

III. INITIAL WORK AT GEORGIA TECH

Initially, an experimental arrangement of small-scale equipment was assembled to try to evaluate various techniques for driving a tank filled with water.

Three arrangements were tried using a tank of 1.25 $ft.^3$ (see Figure 1): (a) one with the valve dumping the pressurized system momentarily to the reservoir; (b) one with the valve in series with the pump to "pulse" the system with high-pressure pulses; and (c) a system similar to the first except having a small orifice by-passing the valve.

The first system gave the largest and sharpest pressure pulsations. The second system was very sluggish, considering the volume of the receiver compared to the pumped volume. The by-pass in the third system merely reduced the amplitude of the pulsations associated with the first system.

Considerable difficulty was encountered with air trapped in the system, either accumulated in filling the tank or from other parts of the system, or dissolved air released during the fluctuating pressure cycles. The problem appeared to be getting the tank filled without trapping some air. This was finally solved by setting the tank vertically with a "bleed-valve" located at the top of the tank to bleed off any air present.

Also, systematic instrumentation problems were encountered with "pick-up" signals, not only occasional pulses which were traced to sudden loads on the AC power lines by others in the area, but also 60-Hertz signals, which sometimes completely masked the signal output of the pressure transducers (1,000 and 500 psi units, being used to measure the 10 - 20 psi signals).

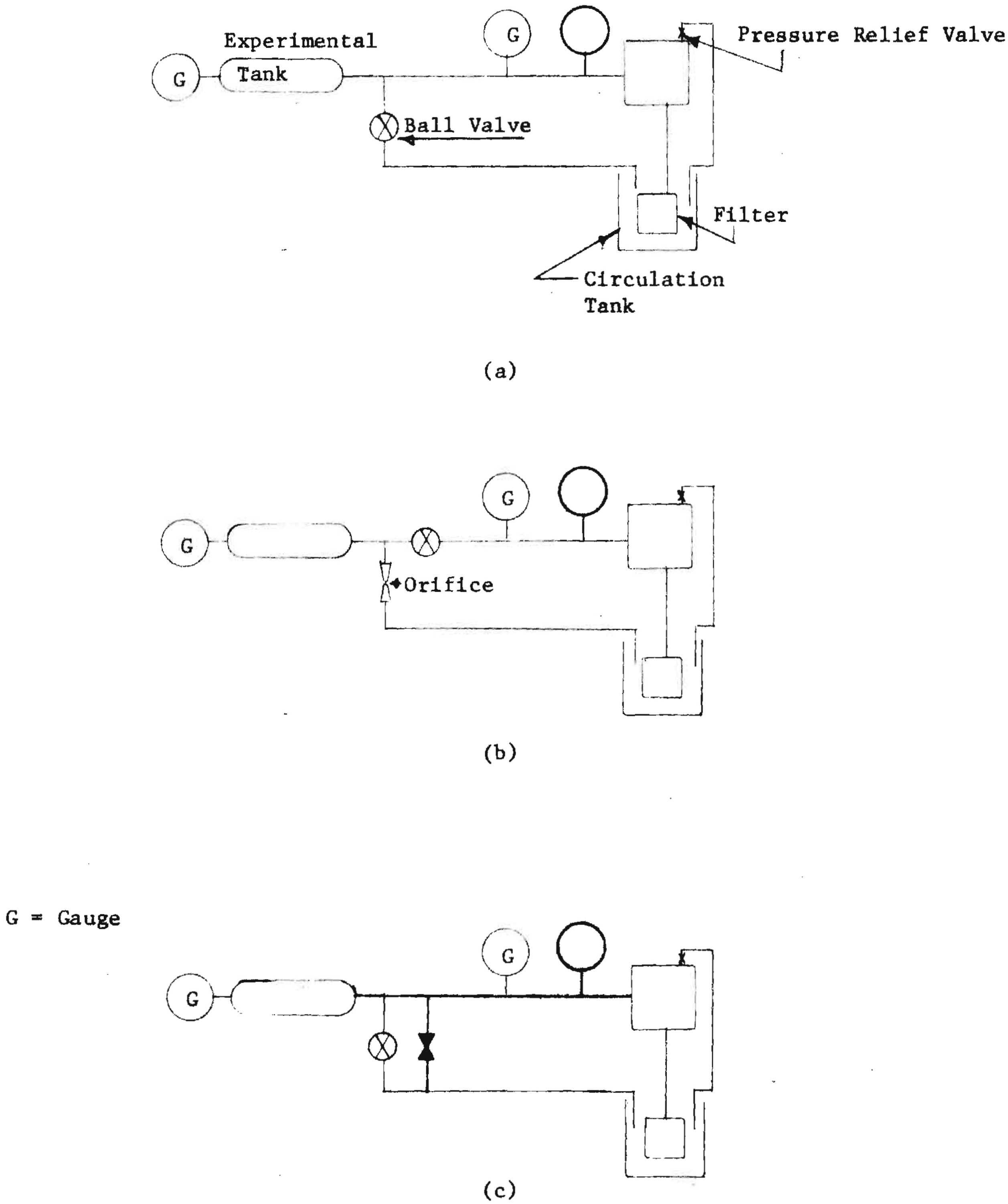

Figure 1. Experimental variations in preliminary tests.

IV. TESTS IN THE RETORT AT GRIFFIN

The experimental retort at Griffin was modified with three flanges and nipples, as shown in Figure 2. Two of these were used to permit monitoring the pressure in the retort with two tourmaline-crystal pressure gauges, prepared as shown in Figure 3. A one-inch-diameter, 3-inch-long nipple was attached 6 inches from the door opening, and to it the modified ball* valve and return line to the reservoir were connected.

The tourmaline-crystal pressure gauges were located as shown in Figure 2. The electrical signals from the gauges were fed directly to a Fairchild dual-beam oscilloscope, which permitted viewing both pressure signals on a common calibrated time axis. The data were recorded by photographing the trace on the face of the oscilloscope with a Polaroid-Land camera. A block diagram of the pressure-measuring equipment is shown in Figure 5.

Two series of tests were conducted in the experimental retort at Griffin: Series I, November 9, 10, 1972; and Series II, February 8, 9, 1973. In the Series I tests, the open area of the ball valve was reduced to 0.125 in^2 by molding an epoxy (Devcon) plug directly into the opening in the ball. In the Series II tests, the ball valve opening was restored to its original area of 0.442 in^2. The data pertinent to these tests are outlined in Table I.

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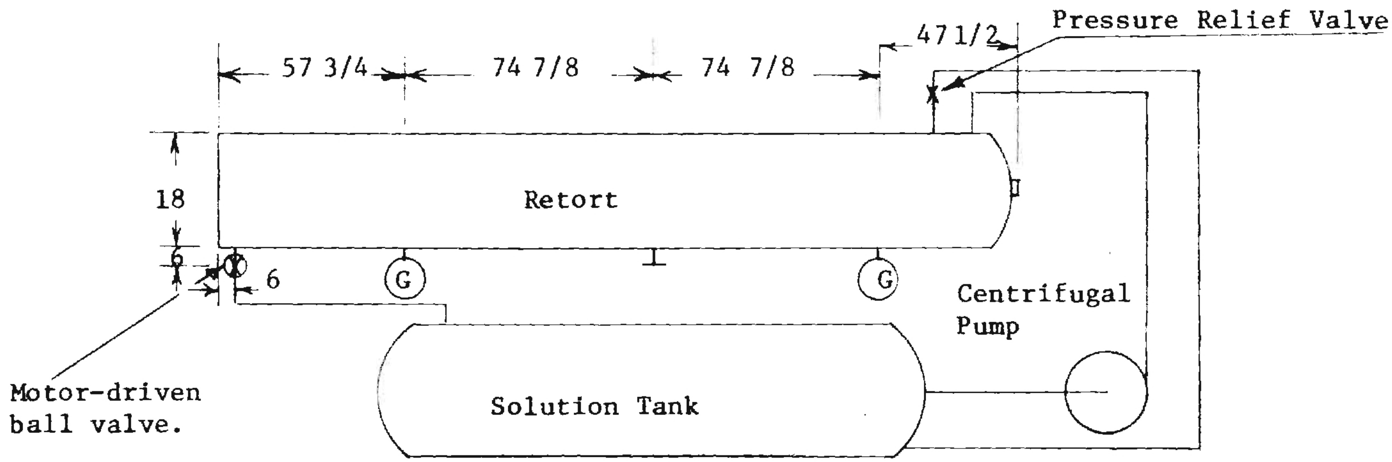
*The ball valve was modified with an auxiliary shaft and seal to improve its life under continuous rotation; see Figure 4.



(dimensions in inches)

Figure 2. Modification of experimental retort at Griffin.

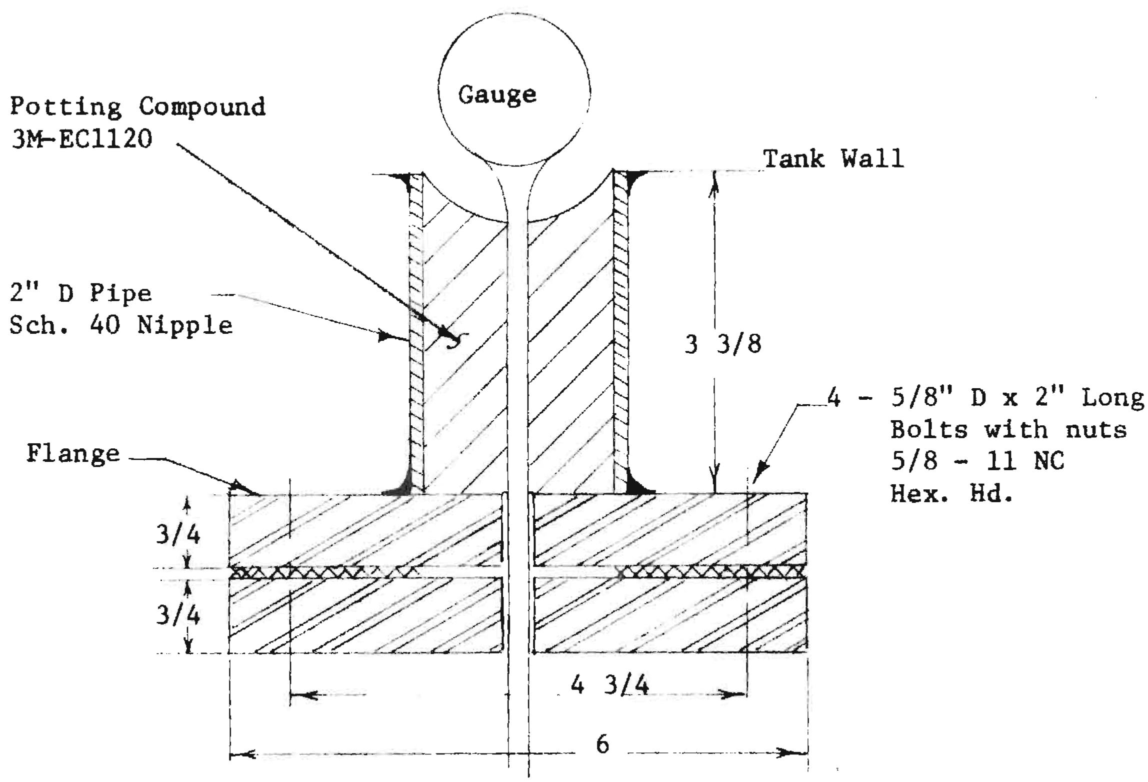


Figure 3. Modification of tourmaline crystal transducers and mounting configuration.

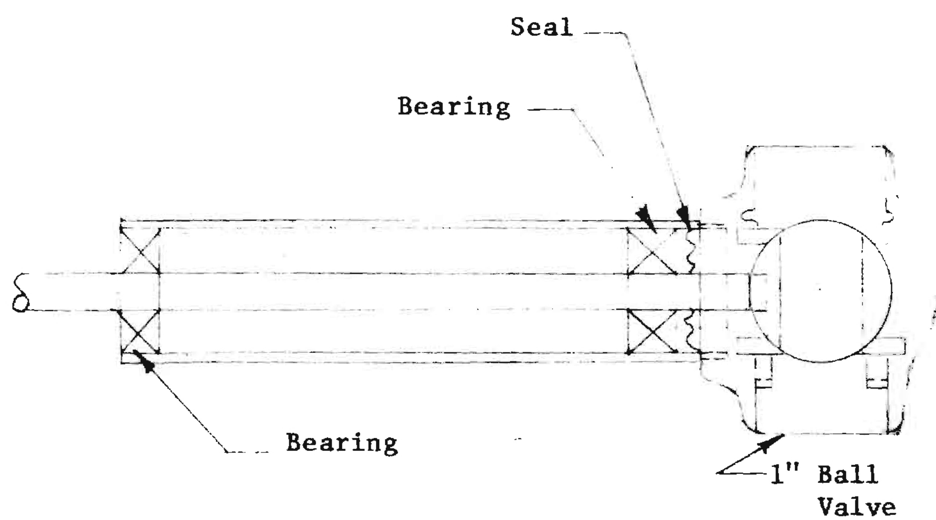


Figure 4. Modification of ball valve seal.

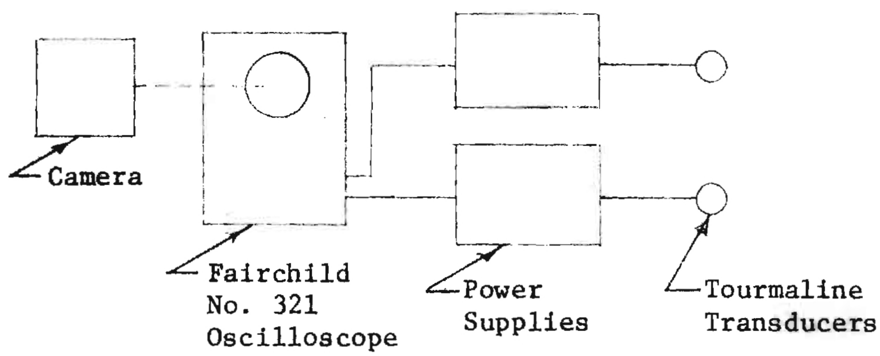


Figure 5. Block diagram of instrumentation at Griffen.

TABLE I

SUMMARY OF DATA FOR GRIFFEN TESTS

Date	Min. From Start Time	Retort Charge	Bd. Ft.	Cu. Ft. Wood Vol.	Sq. Ft. Wood Surface	Cu. Ft. Liquid Vol.	Gal. Solution Take-Up	% Orig. Moisture	Notes
Series I									
Nov. 9, '72		Sol'n. ONLY	-	-	-	36.74	-		
Nov. 9 '72	start	7 ea. 2" x 8" x 16'	149	9.5	170.5	27.2	12		
SYP (1/2 chg)	78								
	95								
Nov. 10 '72	20	17 ea. 2" x 6" x 16'	271	16.9	324	19.8	73		
SYP	45								
	75								
	90								
Nov. 10 '72	start	10 ea. 2" x 6" x 20'	260	16.08	271	20.6	40		
Doug. Fir	70	2 ea. 2" x 4" x 16'							
	120	3 ea. 2" x 4" x 10'							
	165								
Series II									
Feb. 8 '73		Sol'n ONLY	-	-	-	26.74	-		
SYP (1/2 chg)	18	3 ea. 2" x 8" x 16'		9.1	182.3	27.6	37	3.4	100% treatment
	48	8 ea. 2" x 4" x 16'							heart & sapwood
	73								
SYP (3/4 chg)	33	22 ea. 2" x 4" x 16'		13.9	301	22.8	40	7.2	100% treatment
	62								heart & sapwood
	92								
* SYP	42	10 ea 2" x 6" x 16'		19.4	360	17.3	53	5.0	100% treatment

TABLE I

SUMMARY OF DATA FOR GRIFFEN TESTS

(Continued)

Date	Min. From Start Time	Retort Charge	Bd. Ft.	Cu. Ft. Wood Vol.	Sq. Ft. Wood Surface	Cu. Ft. Liquid Vol.	Gal. Solution Take-Up	% Orig. Moisture	Notes
*SYP	65	7 ea. 2" x 8" x 16'							heart & sapwood
	80								
*Doug. Fir	8	16 ea. 2" x 6" x 18'		18.6	356	18.1	35	3.6	100% treat. sapwood
	68	4 ea 2" x 6" x 3'							90% treat. heartwoo
	165								
	207								
	255								

*During these tests, the rotary valve was operating 1/4 of the total treatment time. In other tests, valve operation varied, sometimes probably less than 5% of total treatment time.

V. DERIVATION OF THE RESPONSE CHARACTERISTIC

Consider the system shown in Figure 2. The input flow rate, $\bar{w}$, to the system is continuous, a function of the pump delivery characteristic, and may be represented by

$$\bar{w} = 0.907 \sqrt{128.71 - P} \quad \text{lbs/sec},$$

where P = gauge pressure in the retort.

Fluid is removed from the system by both the by-pass valve (pressure relief valve) and the ball valve. The rate of flow through the relief valve may be written as

$$\bar{w} = 1.88 \sqrt{P} \quad \text{lbs/sec, using the area of the valve} = 0.442 \text{ in}^2.$$

The response of the system is estimated by assuming the valve is opened instantaneously, and observing the pressure-time curve on the oscilloscope. Under this condition, the rate of flow through the valve is

$$\bar{w} = 0.531 \sqrt{P} \quad \text{lbs/sec, Series I (area} = 0.125 \text{ in}^2)$$

$$\bar{w} = 1.88 \sqrt{P} \quad \text{lbs/sec, Series II (area} = 0.442 \text{ in}^2)$$

The accumulation in the tank may be written

$$\text{Accumulation} = \rho_p \left(\frac{V_p}{K_p} + \frac{\pi r^2 LD}{3tE} + \frac{V_w}{K_w} \right) dP = \rho_p C dP,$$

where C represents the expression in parentheses, and

ρ_p = density of the preservative, lbs/ft^3

V_p = volume of preservation, ft^3

K_p = bulk modulus of elasticity for the preservative, psi

r = radius of the retort, ft

L = length of the tank, ft

D = diameter of the retort, in

t = retort wall thickness, in

E = Young's modulus of elasticity for the steel tank, psi

V_w = volume of wood in the retort, ft^3

K_w = bulk modulus of elasticity of wood, psi

$$-\rho_p \left(\frac{V_p}{K_p} + \frac{\pi r^2 LD}{3tE} + \frac{V_w}{K_w} \right) \frac{dP}{d\theta} = 0.907 \sqrt{128.71-P} - 2.41 \sqrt{P}$$

$$\int_{P_o}^{P} \frac{-dP}{0.907\sqrt{128.71 - P} - 2.41\sqrt{P}} = \int_{o}^{\theta} \frac{d\theta}{\rho_p C} ,$$

where θ is time in seconds.

For any one test, the fall of the pressure in the tank can be integrated between the limits of the test, and with the associated time interval, a value of C can be calculated. The equation for the Series II tests is

$$-\rho_p \left(\frac{V_p}{K_p} + \frac{\pi r^2 LD}{etE} + \frac{V_w}{K_w} \right) \frac{dP}{d\theta} = 0.907 \sqrt{128.71-P} - 3.76 \sqrt{P}$$

In order to estimate how this value of compressibility varied with time during the treatment period, a number of tests were conducted in which the valve was momentarily opened manually while the drop in retort pressure was recorded on the oscilloscope as a function of time, Figure 6. The values of C calculated from the resulting data are shown in Table II.

An elementary description of take-up of the preservative by the wood is given in Appendix A. Incorporation of these equations into the system response equation can be accomplished by adding the term $\dot{w} = kP\,(w_o - w)$, where

$\dot{w}$ = $\frac{\text{lbs solution}}{\text{lb dry wood}}$ taken up by the wood per second

k = rate factor, $\frac{1}{\text{psi, sec}}$

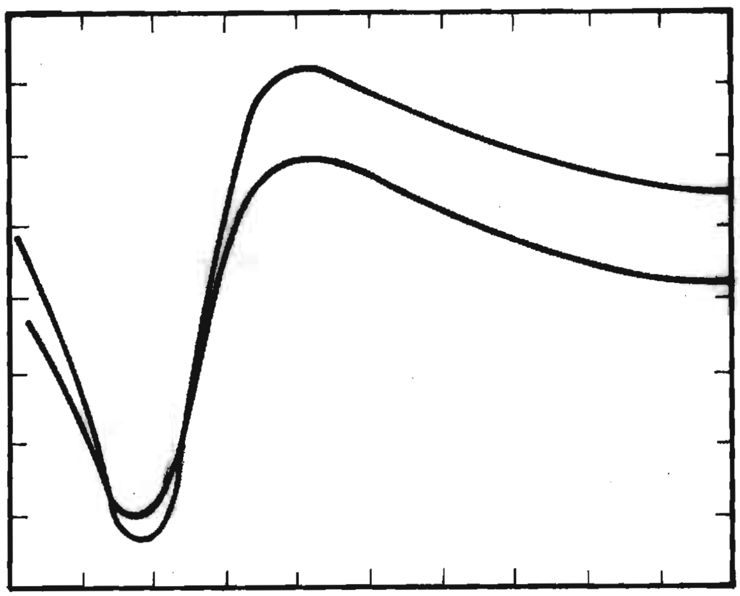
P = retort pressure, psi

w_o = concentration of solution in the wood at saturation, $\frac{\text{lbs solution}}{\text{lb dry wood}}$

and

w = concentration of solution in the wood at any time, $\frac{\text{lbs solution}}{\text{lb dry wood}}$

The estimation of system response equation (Series II) then becomes



0.2 sec/division
Full load Southern Yellow Pine, 42 minutes after start.

Series II

Figure 6. Experimental pressure waveform response determination.

TABLE II

SUMMARY OF CALCULATED "C" VALUES

Date	Time	Retort Charge	Cu. Ft. Wood Vol.	Cu. Ft. Liq. Vol.	Ft^3/psi "C"	PSI K Wood	Ft/sec Vel. of Sound V
Series I							
Nov. 9 '72		Sol'n. ONLY	-	36.74	0.1331		142.5
Nov. 9 '72	start	1/2 chg. SYP	9.5	27.2	0.0200	477	771
	78				0.0118	814	762
	95				0.0105	916	806
Nov. 10 '72	20	Full chg. SYP	16.9	19.8	0.0245	693	534
	45				0.0218	779	566
	75				0.0162	1050	654
	90				0.0141	1207	700
Nov. 10 '72	start	Full chg. Dougl Fir	16.08	20.6	0.0136	1191	602
	70				0.0138	1174	597
	120				0.00828	1967	767
	165				0.00637	2566	871
Series II							
Feb. 8 '73		Sol'n ONLY		36.74	0.0153		420
	18	1/2 chg. SYP	9.1	27.6	0.0124	741	744
	48				0.00784	1180	927
	73				0.00989	932	830
	33	3/4 chg. SYP	13.9	22.8	0.00945	1488	849
	62				0.00645	2193	1019
	92				0.00982	1432	834
Feb. 9 '73	42	Full chg. SYP	19.4	17.3	0.00797	2463	923
	65				0.00681	2888	995
	80				0.00915	2142	864
	8	Full Chg. Dougl Fir	18.6	18.1	0.00804	2341	778
	68				0.00867	2169	750
	165				0.00641	2946	869
	207				0.00393	4851	1097
	255				0.00806	2336	778

$$-\rho_p C \frac{dP}{d\theta} = 0.907\sqrt{128.71-P} - 3.76\sqrt{P} - kP(w_o - w)W,$$

where W is the pounds of dry wood in the retort.

However, the contribution of the last term during the quick opening of the valve (less than one second) is probably negligible in terms of the other factors.

VI. EXPERIMENTAL DATA

At the beginning of each series of tests, the retort was filled with preservative solution only (no wood) to obtain initial data on the tank. It was noted that after the tank was drained the first time, an 8-inch cord of foam was present in the retort. Considering that this volume was at atmospheric pressure after draining the retort, the volume at 70 psig* would have been

$$0.725 \times \frac{15}{85} = 0.127 \text{ ft}^3$$

This quantity of air (foam) would not account for the uncommonly high value of "C" determined from the Series I test. The Series II value of "C" for the "solution only" test is more in line with the value expected.

In the process of impregnating wood with the preservative, air in the wood structure must, at least in part, be displaced. Consequently, the displaced air is in the preservative as minute bubbles, some of which aglomerate into larger bubbles and separate out at the top of the retort; all this air contributes to a change in the effective compressibility of the wood-solution-retort system. For this reason, only the overall value of the bulk compressibility of the system has been estimated as

$$C = \frac{V_p}{K_p} + \frac{\pi r^2 LD}{3tE} + \frac{V_w}{K_w} .$$

A term, $\frac{V}{P}$, for air has been left off, purposely, since no value for the volume of air in the retort was measured nor could one be realistically approximated.

The velocity of an acoustic wave propagation in the tank may be written

$$v = \frac{12}{\sqrt{\frac{1}{gV}\left(\frac{V_p}{k_p} + \frac{\rho_p \pi r^2 LD}{3tE} + \frac{\rho_w V_w}{K_w}\right)}}$$

---

*Maximum pressure in the retort during the initial Series I test.

where:

ρ_w =density of the wood material, lbs/ft^3

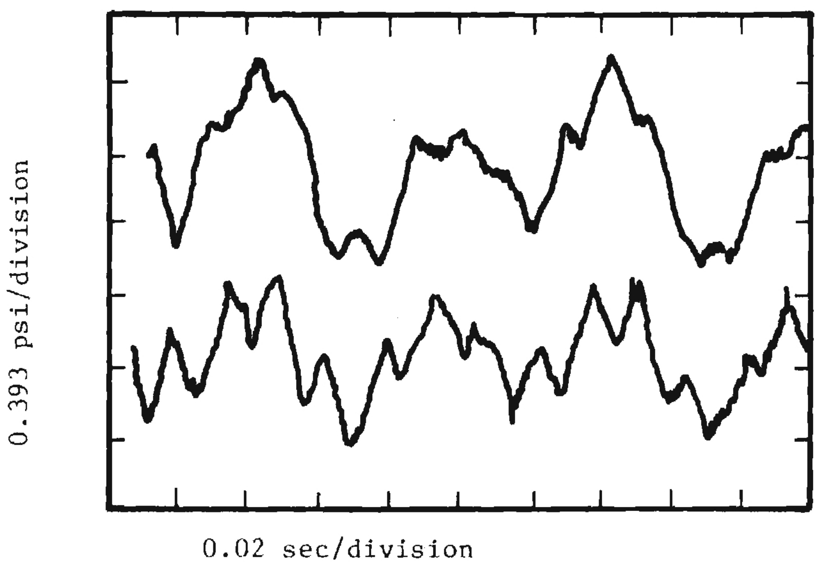
g = constant, 32.2 ft/sec^2

V = volume of the system, 36.74 ft^3

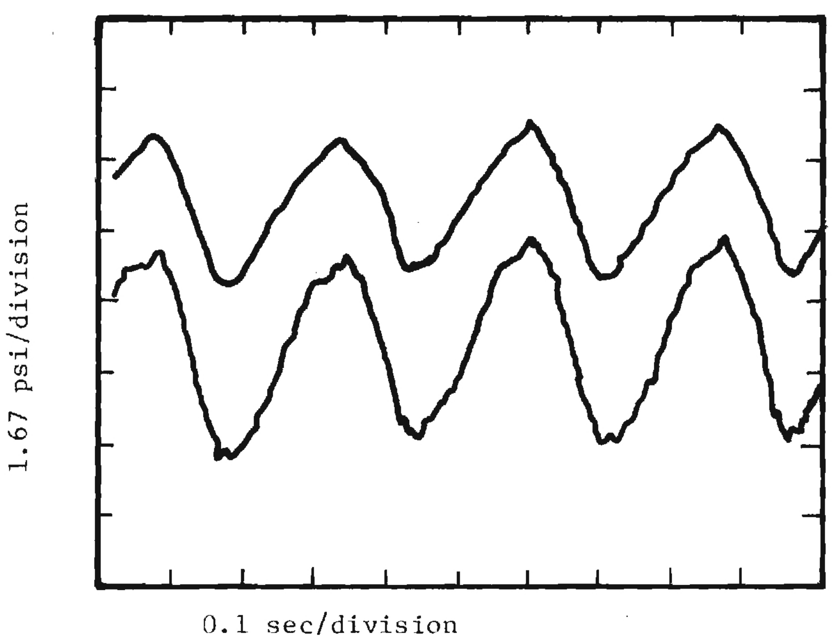
v = velocity of propagation, ft/sec

The low propagation velocity indicated in Table II may be attributed to the air volume in the tank, in the form of foam or to a particularly compressible solution, because of dissolved air.

Waveforms of the tank with solution only are shown in Figure 7. Waveforms observed during treatment of wood charges are shown in Figures 8, 9, and 10. The particular parameters associated with each are noted on the waveform. The pressure fluctuation is of the order of 3-5 psig peak-to-peak (1.5 to 2.5 psig each side of the mean).

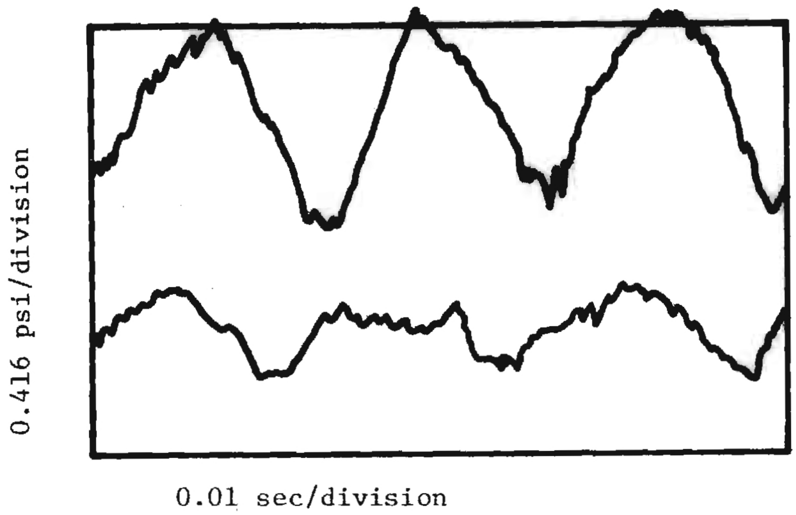


a) Series I

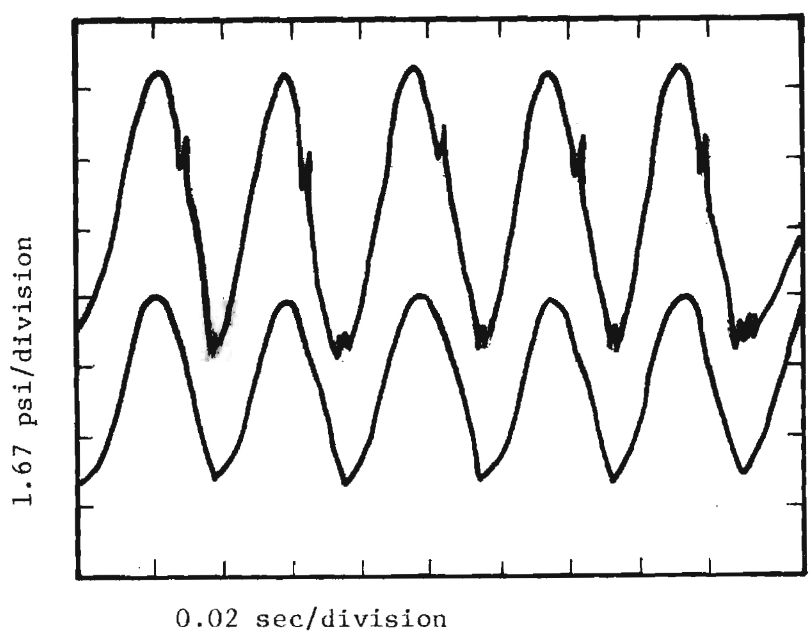


b) Series II

Figure 7. Experimental pressure waveforms - solution only in retort.

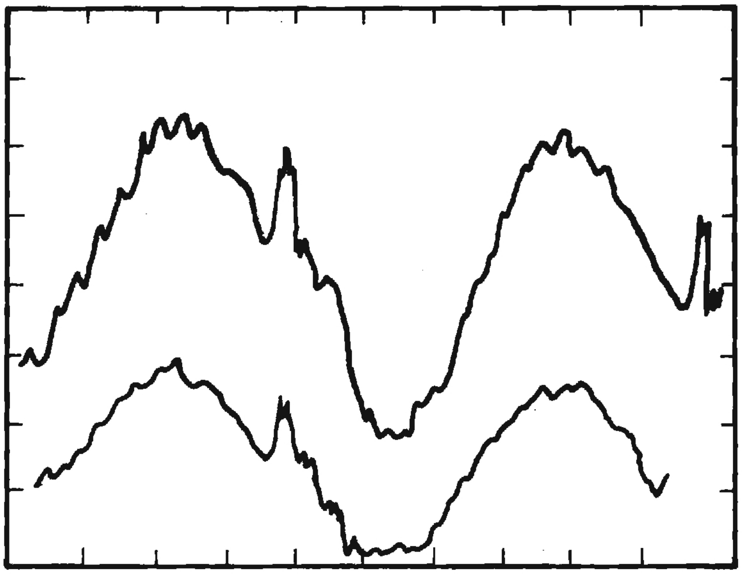


Series I, 1/2 load southern yellow pine, at start



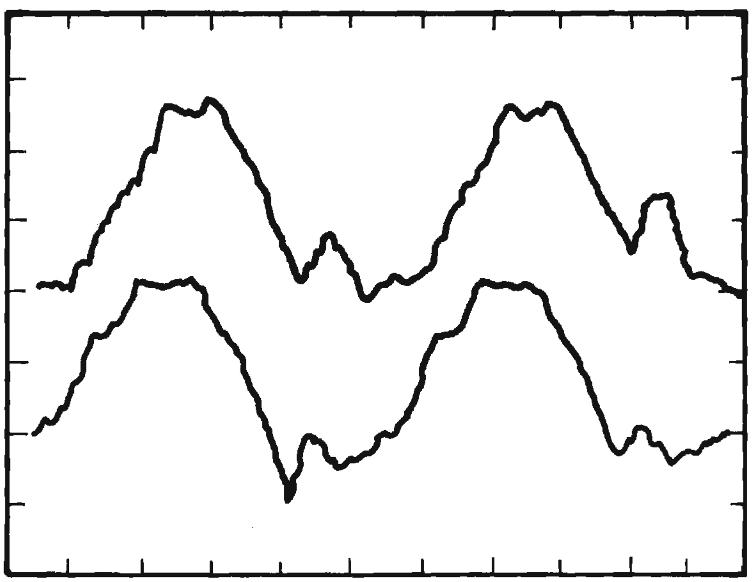
Series II, 1/2 load southern yellow pine, 13 min.
fter start.

Figure 8. Experimental pressure waveforms.



0.02 sec/division

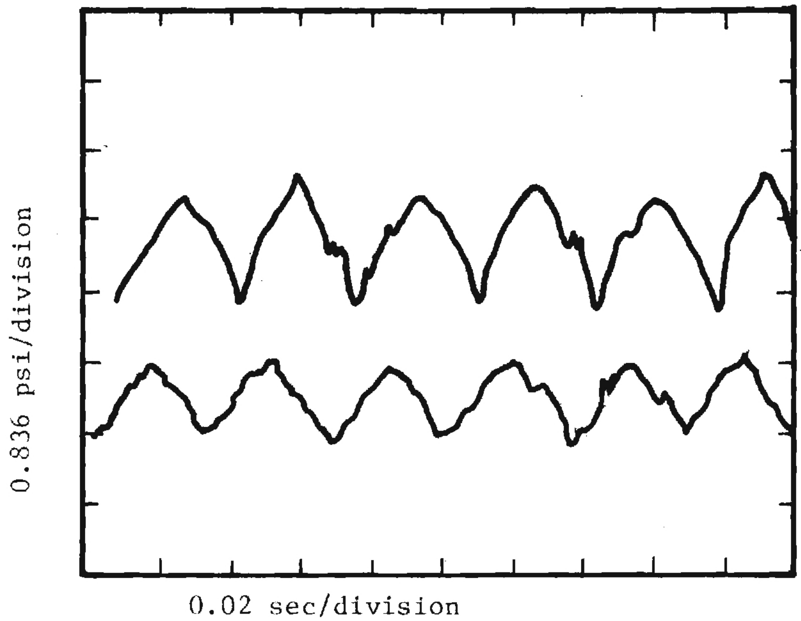
Series I, full load, southern yellow pine, 1 hour after start.



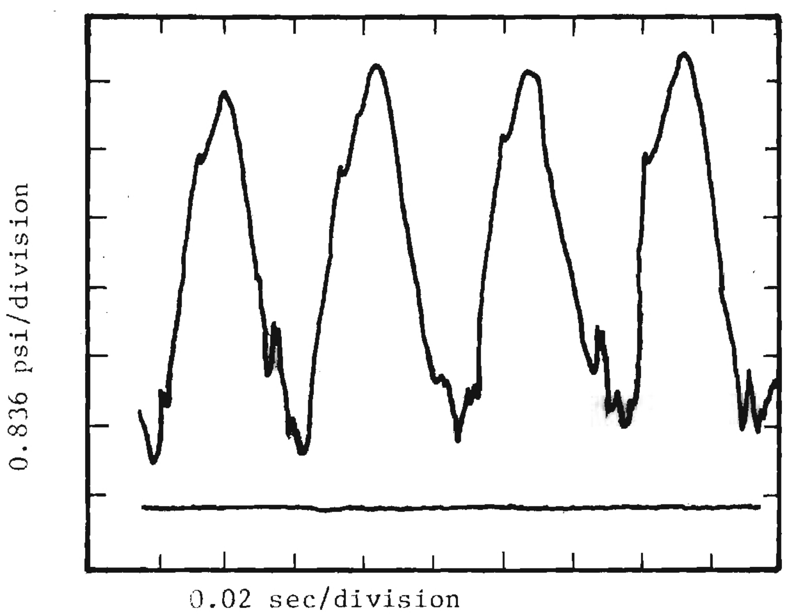
0.02 sec/division

Series II, full load southern yellow pine, 1 hour 17 min. after start.

Figure 9. Experimental pressure waveforms.



Series I, full load, douglas fir, 1 hour 5 min. after start.



Series II, full load douglas fir, 4 hours after start.

Figure 10. Experimental pressure waveforms.

VII. DISCUSSION OF THE DATA

The compressibility of the system may be estimated by monitoring the response of the system to the sudden opening of the ball valve. A number of these tests were conducted, and the results of the calculations are shown in Table II, and plotted in Figure 11 as a function of treatment time.

Wood is nonhomogeneous, all pieces of lumber being unique in various factors, such as parallelism of the grain to the long dimension of the piece of wood, fraction of heart versus sap-wood, moisture content, and macroscopic density, porosity, etc. Consequently, each retort load of lumber can be expected to have a different overall compressibility.

Further, the wood takes up preservative as it releases air contained in its macrostructure. Resistance to preservative take-up may be related to the tenacity of the macrostructure to hold its contained air. The ease with which the wood releases its air will in all probability vary from piece to piece, and hence the amount of released air in the retort at any one time is unknown, although it probably can only increase during any one treatment cycle.

To account for the air-released in the calculation of the effective compressibility would require adding a term

$$\frac{V_{air}}{K_{air}}$$

to the term represented by C. However, the volume of air in the system at any time is unknown. For this reason, the values of the overall compressibility may be realistic for the particular load of wood in the retort, but must be used carefully when considering other loads and other retorts. The air released in the solution take-up during operation of the valve might be bled off by readjusting the relief valve to a value corresponding to the mean pressure in the oscillating cycle. During the tests reported herein, the relief valve was set for 110-125 psig, as in the normal treatment cycle, but the internal pressure in the retort dropped to 60-75 psig during operation of the ball valve.

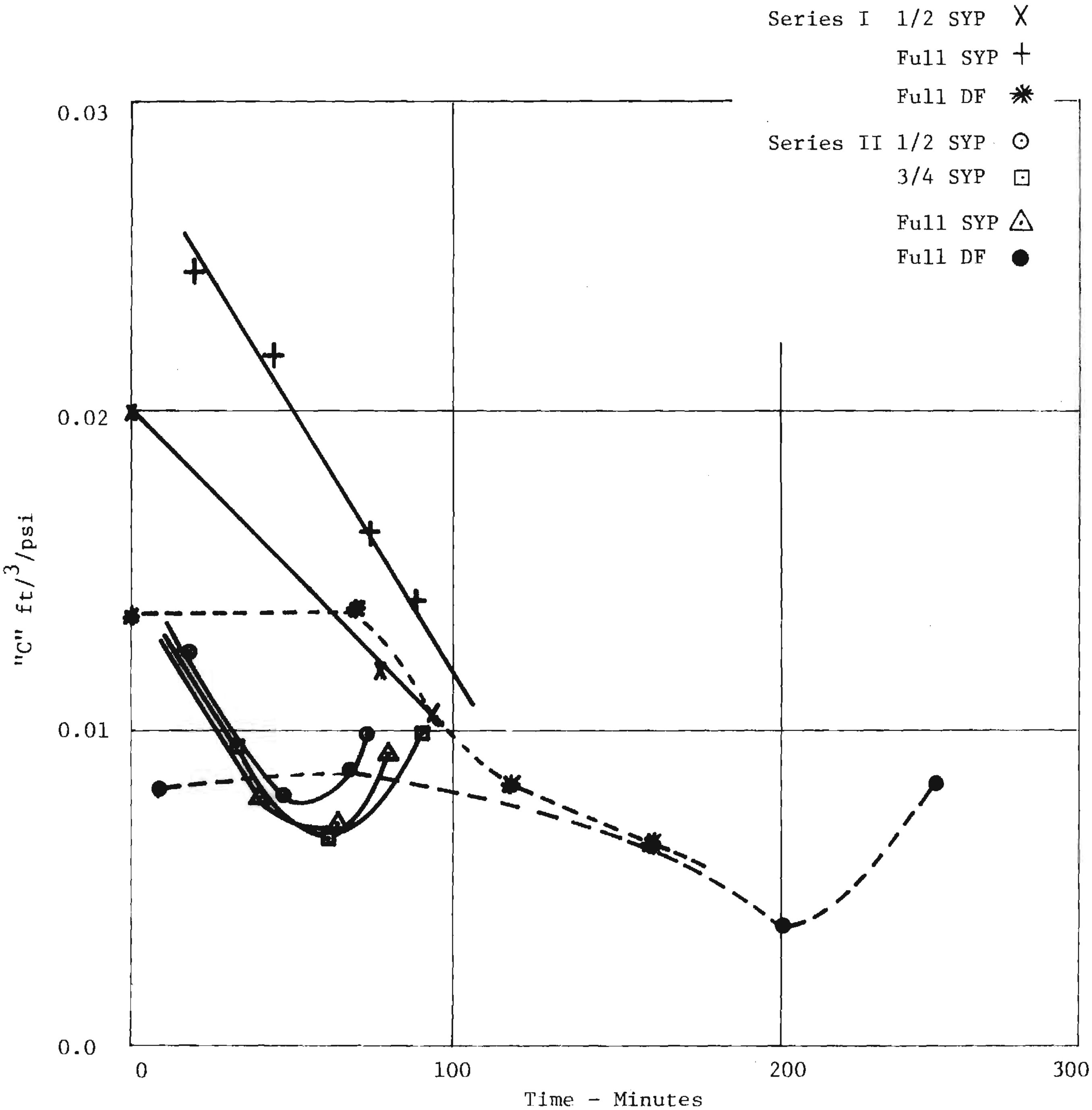


Figure 11. Variation of "C" with time.

VIII. ELECTRONIC RESONANCE STABILIZER

During treatment of the wood and adjustment of the rotation rate of the valve, very evident physical and audible changes in the response of the retort were observed. These changes were assumed to be associated with resonance of the tank, since the noise associated with the valve operation increases significantly with "resonance," and the physical (external) vibrations of the tank became a maximum at this setting of the valve operation rate. The magnitude of the pressure pulses also peaked at this value of valve rotation rate. As the wood takes up treatment solution, this resonance shifts to another rotation rate, however, as can be seen in the data in Table II.

At the request of the sponsor, an electronic device to hold the system at resonance by automatic adjustment of the valve rotation rate was designed, fabricated, installed, and tested in place at the Griffin plant. This unit is briefly described in Appendix B.

IX. CONCLUSIONS

The results of the calculations are shown in Table II and the effectiveness (completeness) of the treatment is summarized in Table I. Several comments appear to be pertinent.

(1) Treatment appeared to be essentially complete, for both heart and sapwood using full (conventional) treatment time with the oscillatory pulsations applied approximately one-fourth of the time. No studies were made to examine the effect of shorter treatment time or reduced oscillatory fraction of the overall time on degree of treatment of the wood.

(2) The curves of compressibility versus treatment time appear to follow an irregular pattern.

(3) The reproducibility of the data appears to be fair, within any test (loading) of the retort. However, the curves of Figure 12 attest to the non-reproducibility of similar tests on different dates. This may be due to the wood variation alone, to the fact that the pressure fluctuation was greater in the Series II tests because of the larger valve opening, or a combination of the two factors.

(4) An effective, low-cost method appears to have been developed to produce 3 to 5 psi pulsations of the pressure in a wood treatment retort.

X. RECOMMENDATIONS

In studying the effects of the low-frequency oscillator on the treatment of wood preservative, is recommended that:

1) A series of tests be conducted with different treatment times, using the frequency stabilizer to determine the optimum treatment cycle.

2) A series of tests be conducted with different initial pressures using the frequency stabilizer, to determine the optimum treatment pressure.

3) A series of tests be conducted, using the frequency stabilizer, with different fractional valve operating times to determine the optimum fraction of time to operate the valve.

4) Tests should be conducted to determine if there is an optimum amplitude of the pressure pulsation.

5) Tests should be conducted to determine if readjustment of the relief valve setting to permit air/gas bleed-off during the valve operation period makes a significant difference in either treatment time or penetration*.

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*It is not desirable to put the valve connection to the tank in the bled-off line, since this could lead to a gas-bound valve and possibly more severe "water-hammer" type of impact stresses in both valve and piping particularly early in the treatment cycle.

BIBLIOGRAPHY

1. R. Z. Page and B. E. Reed, Jr., U. S. Patent Serial 564, 506.

2. J. H. Barnett, Jr., Shock-Wave Pressure Treatments in Wood Preservation presented at the Southern Pressure Treaters Association meeting in New Orleans, Nov. 6, 1968. (reproduced in Cross Ties, May 1969)

Appendix A

ESTIMATE OF THE ABSORPTION OF WOOD PRESERVATIVE SOLUTION IN WOOD

This appendix describes one method of accomplishing the reduction of data associated with the treatment of wood with preservative solution to a useful form.

Let ω be defined as the lbs of solution absorbed at any time per lb of dry wood. Also let ω_o be the lbs of solution absorbed per lb of dry wood at saturation (100% treated wood). The preservative is a very dilute aqueous solution; consequently the distinction between water and solution is unnecessary. Assume the rate of solution take-up, $\dot{\omega}$, measured in lbs of water per lb of dry wood per second, is proportional to the retort pressure, P, and to the factor $(\omega_o - \omega)$, that is,

$$\dot{\omega} = kP\ (\omega_o - \omega),$$

where

$$k = \frac{\text{lbs } H_2O}{\text{lb dry wood, psi, sec. lbs } H_2O\text{/lb dry wood}} = \frac{1}{\text{psi, sec}} .$$

Then, the solution take-up per lb of dry wood, $\Delta\omega$, over a period of time, θ, is

$$\Delta\omega = \int_0^\theta \dot{\omega} d\theta = \int_0^\theta kP\ (\omega_o - \omega)\ d\theta ,$$

where θ is time in seconds.

During pressurization, $P \simeq a\theta$, where a = rate of pressure change; during the remainder of the treatment cycle, P = constant. The equation may be integrated separately under these two conditions. If pressurization occurs in 5 minutes (300 sec), $a = \frac{125}{300} = 0.417$ psi/sec.

$$\Delta\omega = \int_0^{300} 0.417k\theta\ (\omega_o - \omega)\ d\theta$$

$$\int_{\omega_1}^{\omega_{300}} \frac{d\omega}{\omega_o - \omega} = 0.417k \int_0^{300} \theta d\theta$$

$$-\ln \frac{\omega_o - \omega_{300}}{\omega_o - \omega_1} = \frac{0.417k\theta^2}{2} = \frac{0.417k(300)^2}{2} = 18{,}765k$$

$$\frac{\omega_o - \omega_{300}}{\omega_o - \omega_1} = \exp(-18{,}765k)$$

where

ω_1 = the value of ω at start,

and

ω_{300} = the value of ω at 300 secs, i.e., the end of the period of increasing pressure,

At constant pressure,

$$d\omega = k(125) \quad (\omega_o - \omega_{300})d\theta$$

$$\int_{\omega_{300}}^{\omega_\theta} \frac{d\omega}{\omega_o - \omega} = \int_{300}^{\theta} 125k\,d\theta$$

$$-\ln \frac{\omega_o - \omega_\theta}{\omega_o - \omega_{300}} = 125k\ (\theta-300)$$

$$\frac{\omega_o - \omega_\theta}{\omega_o - \omega_{300}} = e^{-125k\ (\theta-300)} ,$$

where

ω_θ = the value of ω at time θ.

Note that a plot of this integrated equation produces a straight line on a semi-logarithmic paper.

Combining the two integrated equations gives

$$\frac{\omega_o - \omega_\theta}{\omega_o - \omega_1} = e^{-k(125\theta - 18,735)}$$

Solving for the final value,

$$\omega_\theta = \omega_o \left[1 - e^{-k(125\theta - 18,735)} \right] + \omega_1 e^{-k(125\theta - 18,735)}$$

To estimate rate of take-up, differentiate ω,

$$\dot{\omega} = 125k\ (\omega_o - \omega_1)\ e^{-k(125\theta - 18,735)}$$

Under the assumptions above, maximum rate of take-up occurs at the end of the pressure increase, and the value would then be

$$\dot{\omega} = 125k\ (\omega_o - \omega_1)\ e^{-18,765} \quad \text{lbs. solution/lb. dry wood}$$

It is realized that other factors are involved, such as the effect of oscillating pressure, etc. However, with different values of k, the analysis may be useful for both standard and pulsed treatment cycles, if the average pressure is used during pulsation.

Assuming $\omega_o = 1$, the calculated values below are obtained for the November 1973 tests.

Load	ω_1	ω_o	ω_θ *	k $\left(\frac{1}{\text{psi, sec}}\right)$	$\dot{\omega}_{max}$ $\frac{\text{lbs. solution}}{\text{lb. dry wood, sec.}}$	θ sec
Full SYP	0.0526	1.0	0.986	7.25×10^{-6}	7.49 x 10-4	4,800
Full D Fir	0.0373	1.0	0.586	4.46×10^{-7}	5.32×10^{-5}	15,300

* Calculated from amount of solution take-up and the quantity of wood in retort.

Appendix B

OPERATING INSTRUCTIONS FOR OSMOSE PROCESS CONTROLLER

Description

The process controller consists of five basic units: the pressure transducer, the set point control box, the coupling unit, the Wood & Sons motor speed controller, and the motor-driven valve assembly. The motor driven-valve assembly and motor speed controller function as a unit and will not be discussed separately: The pressure transducer senses the oscillating pressure within the retort and compares its value to the desired value which is entered by the ten-turn control knob on the set point control box. The output of the set point control box is connected through the coupling unit to the motor speed controller which controls the motor-driven valve.

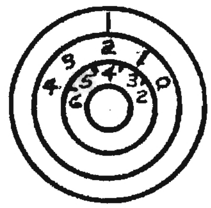
Start Up Procedure

First ascertain that the power cords for both the motor speed controller and set point controller are connected to 110V AC. Next turn "On-Off" switch on the set point controller to "On" and allow approximately five minutes for the controller to stabilize. After warm-up, pull out "On-Off" switch on the motor speed controller to place the motor speed controller in the "On" state. (Note: This "On-Off" switch is a nylon knob located on the left of the panel of the motor speed controller). The system is now ready for operation and when the "Forward-Reverse" knob on the motor speed control is pulled out, the motor will begin running.

Adjustment

Following the start-up procedure the motor speed will be controlled by the set point controller. The retort can be "Tuned" to resonance by adjustment of the knob on the set-point controller labeled "Set Point." Resonance is best determined by observing the end of the retort and adjusting the "Set-Point" knob for maximum oscillation of the retort. Due the time lags in the system, this adjustment must be done slowly to allow the control system to stablize at each new value of the set point

Observed resonance has occurred with the set-point knob set between 2.3 and 2.5. Note that the set point control is a ten-turn unit and is read as shown in the figure below:



Setting Shown

is 2.4

Once the system is tuned to resonance, the controller will hold the resonant condition.

Shut Down Procedure

To shut down the control system it is only necessary to push in the "Forward-Reverse" switch on the motor speed controller. This stops the motor; it may be necessary to "Bump" this knob several times to stop the motor with the valve in the closed position. After the motor is stopped, the "On-Off" switches on both the set point controller and the motor speed controller should be turned "Off." If the system is to be shut down for a short period of time, it is advisable that the power to the set point controller be left on to eliminate waiting for it to warm up when operation is resumed.

Block Diagram

A block diagram of the control system is shown as Figure 12.

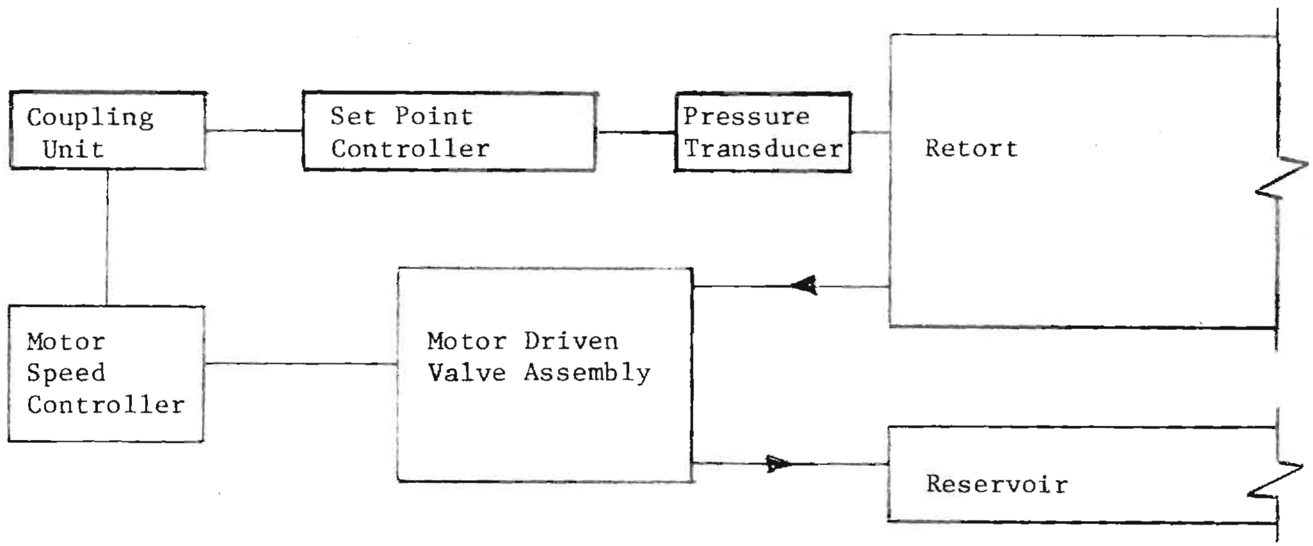


Figure 12. Block diagram of the experimental process control system.